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Effects of High-Intensity Functional Training on Muscle Performance and Body Composition During the Ramadan Fasting Period

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Abstract

The aim of this study is to examine the effects of functional training performed during the daytime fasting period in Ramadan on changes in body composition, muscle strength, and muscle hypertrophy, with respect to training timing. The study included 32 healthy male university students enrolled at Karabük University who maintained daytime fasting between suhoor and iftar during Ramadan. Participants were divided into two groups based on training timing (pre-iftar and post-iftar), and a functional training program was implemented for four weeks. Body composition, circumferential measurements, and isometric muscle strength were assessed at two time points: before the start of the training program (pre-test) and after completion of the four-week training program (post-test). Data were analyzed using the SPSS 25 statistical software package. No significant differences were observed between the pre-iftar and post-iftar training groups with respect to baseline demographic characteristics and body composition parameters ($p > 0.05$). In pre-training between-group comparisons, significant differences were identified only in certain upper-extremity muscle strength parameters and in isometric ratings of perceived exertion (RPE) ($p < 0.05$). Following the four-week functional training program, significant between-group differences were observed solely in gluteus maximus muscle strength values ($p < 0.05$). Within-group analyses revealed statistically significant improvements in multiple parameters related to muscle mass and muscle strength in both training timing conditions ($p < 0.05$). However, while pre-iftar training was predominantly associated with strength gains in upper-extremity and postural muscle groups, post-iftar training elicited more pronounced adaptations in body composition indicators and lower-extremity muscle strength. This study provides an original contribution to the field by examining the feasibility and effects of high-intensity functional training during Ramadan from the perspective of training timing. The findings indicate that planning training sessions in relation to nutritional status may play a determining role in the direction and magnitude of physiological adaptations occurring during Ramadan. The observation that these adaptations were more pronounced particularly in large muscle groups underscores the role of training timing in musculoskeletal responses. The supportive effects of postprandial exercise on muscle protein synthesis and fat metabolism suggest that the present findings are consistent with the existing literature. Overall, these results

demonstrate that training timing during Ramadan is a critical determinant in shaping the direction and extent of physiological adaptations. In this context, the study offers a scientifically grounded and practically applicable framework for planning training programs during Ramadan.

Keywords: ramadan fasting, functional training, strength, hypertrophy.

Özet

Ramazan Orucu ve Yüksek Şiddetli Fonksiyonel Antrenmanın Vücut Kompozisyonu, İzometrik Kuvvet ve Hipertrofiye Etkisinin İncelenmesi

Bu çalışmanın amacı, Ramazan ayında gündüz oruç dönemi boyunca gerçekleştirilen fonksiyonel antrenmanın, antrenman zamanlamasına bağlı olarak vücut kompozisyonu, kas kuvveti ve kas hipertrofisinde meydana gelen değişiklikleri incelemektir. Çalışmaya, Karabük Üniversitesinde öğrenim gören ve Ramazan ayında sahur–iftar arasında gündüz orucunu sürdüren 32 sağlıklı erkek üniversite öğrencisi dâhil edilmiştir. Katılımcılar, antrenman zamanlamasına göre iftar öncesi ve iftar sonrası olmak üzere iki gruba ayrılmış ve dört hafta süreyle fonksiyonel antrenman programı uygulanmıştır. Vücut kompozisyonu, çevresel ölçümler ve izometrik kas kuvveti değerleri antrenman programının başlamasından önce (ön test) ve dört haftalık antrenman programının tamamlanmasından sonra (son test) olmak üzere iki zaman noktasında değerlendirilmiştir. Verilerin analizinde SPSS 25 paket programı kullanılmıştır. İftar öncesi ve iftar sonrası antrenman grupları arasında başlangıç demografik özellikleri ve vücut kompozisyonu parametreleri açısından anlamlı bir fark bulunmamıştır ($p>0,05$). Antrenman öncesi gruplar arası karşılaştırmalarda yalnızca bazı üst ekstremite kas kuvveti parametreleri ve izometrik algılanan zorluk düzeyi (RPE) değerlerinde anlamlı farklılıklar belirlenmiştir ($p<0,05$). Dört haftalık fonksiyonel antrenman programı sonrasında gruplar arasında yalnızca gluteus maximus kas kuvveti değerlerinde anlamlı farklılıklar saptanmıştır ($p<0,05$). Grup içi analizlerde, her iki antrenman zamanlamasında da kas kütlesi ve kas kuvvetine ilişkin çok sayıda parametrede istatistiksel olarak anlamlı iyileşmeler gözlenmiştir ($p<0,05$). Bununla birlikte, iftar öncesi antrenman ağırlıklı olarak üst ekstremite ve postural kas gruplarında kuvvet artışları ile ilişkiliyken, iftar sonrası antrenman vücut kompozisyonu göstergeleri ve alt ekstremite kas kuvvetinde daha belirgin adaptasyonlar ortaya koymuştur. Çalışma Ramazan ayında yüksek şiddetli fonksiyonel antrenmanın uygulanabilirliğini ve etkilerini antrenman zamanlaması perspektifinden ele alarak alana özgün bir katkı sunmaktadır. Antrenmanların nutrisyonel durumu ile ilişkili olarak planlanmasının, Ramazan döneminde gelişen fizyolojik adaptasyonların yönü ve büyüklüğü üzerinde belirleyici olabileceği ortaya konmuştur. Bu değişimlerin özellikle büyük kas gruplarında daha baskın düzeyde saptanması, antrenman zamanlamasının kas-iskelet sistemi üzerindeki rolünü vurgulamaktadır. Beslenme sonrası uygulanan egzersizin kas protein sentezi ve yağ metabolizmasını desteklemesi, elde edilen bulguların mevcut literatürle tutarlı olduğunu göstermektedir. Bu sonuçlar, Ramazan döneminde antrenman zamanlamasının fizyolojik adaptasyonların yönünü ve düzeyini belirlemede kritik bir belirleyici olduğunu ortaya koymaktadır. Bu bağlamda çalışma, Ramazan ayında uygulanacak antrenmanların planlanmasına yönelik bilimsel dayanaklı ve pratik açıdan uygulanabilir bir yaklaşım ortaya koymaktadır.

Anahtar Kelimeler: gündüz oruç dönemi, fonksiyonel antrenman, kuvvet, hipertrofi.

INTRODUCTION

Fasting has been a fundamental component of various religious and spiritual practices for thousands of years (30). It is also observed in belief systems such as Buddhism, Hinduism, Jainism, and Taoism. For individuals who practice Islam, fasting is observed throughout the month of Ramadan and is one of the five pillars of the religion (25). Depending on geographic location and the time of year, Ramadan fasting involves abstaining from food, drink, sexual activity, and tobacco products for approximately 12 to 20 hours a day (1).

Due to prolonged fasting, Ramadan can result in a reduction in body mass index and decreased levels of fasting insulin and glucose. Additionally, reductions in leptin, adiponectin, triglyceride levels, and pro-inflammatory cytokines have been observed. These physiological changes may provide protective effects against cardiovascular diseases, diabetes, and cancer (12). Ramadan fasting resembles intermittent fasting in that it includes alternating periods of feeding and fasting. However, the main difference between the two is that water consumption is permitted during intermittent fasting (30).

Decreases in total energy and fluid intake, fewer daily meals, and alterations in dietary patterns during Ramadan can lead to acute dehydration. Moreover, impaired sleep quality, reduced total protein synthesis, and low energy intake may result in negative physiological outcomes. Changes in nutrition and sleep patterns may produce both physiological and psychological effects, posing challenges for Muslim athletes who continue training or competing during Ramadan. Reduced intake of nutrients and fluids can significantly affect exercise performance, post-exercise recovery, and training adaptations. These outcomes may vary depending on the length of fasting, seasonal and geographic factors, and the type of performance tests applied (14,31).

There is evidence in the literature indicating that fasting negatively affects athletic performance (1,22,29). On the other hand, some studies suggest that Ramadan fasting increases fat oxidation (4, 24). Fasting supports a healthy detoxification process in the human body and increases fat oxidation to meet energy needs by reducing carbohydrate use after more than 8 hours of food deprivation (16). After 4–6 hours of fasting, once glycogen stores are depleted, the body begins to synthesize glucose in the liver through gluconeogenesis from amino acids, glycerol, and ketone bodies (21).

Compared to exercise performed in a fed state, exercise in a fasted state leads to greater intramuscular lipid breakdown in type I fibers and greater glycogen depletion in type II fibers. Furthermore, endurance training in a fasted state over six weeks has been shown to increase the amount of fatty acid binding proteins in the muscle (28).

Functional training is a type of exercise planning that has emerged within the evolving structure of the fitness concept. The primary goal of this approach is to improve general mobility and promote strength development across all muscle groups (9). For the body to move efficiently, it must be viewed as a kinetic chain in which energy and force are transferred successfully from one part or joint of the body to another. Weak links within this chain can limit the overall strength of the entire system. Therefore, functional training aims to strengthen any weaknesses or imbalances that may exist at various joint positions. Frequent repetition of movements enhances motor patterns and increases force production capacity (3). Due to these characteristics, functional training is considered an appropriate method for examining potential changes in performance and strength during periods of restricted energy intake. Although the effects of functional training on balance, strength, and physical performance have been documented in the literature, data regarding the application of this training modality under fasting conditions during the month of Ramadan remain limited (32).

The contribution of strength training to performance is fundamentally based on two main mechanisms: nervous system adaptations and muscle hypertrophy. While motor unit activation, neural synchronization, and the development of movement technique are more prominent in the initial period (19), structural changes in muscle fibers and hypertrophic responses are observed during regular and intense training (20).

Considering this information, the impact of exercising in a fasted state on body composition and strength development has not been sufficiently clarified in the literature. The aim of this study is to examine the changes in body composition, muscle strength, and muscle hypertrophy resulting from functional training performed during the month of Ramadan by fasting individuals.

METHOD

Participants and procedure

A total of 32 sedentary male volunteers from Karabük University participated in the present study. Written informed consent was obtained from all participants, and the study protocol was approved by the Karabük University Ethics Committee. All assessments were conducted at the Performance Laboratory of Hasan Doğan School of Physical Education and Sports.

The study was carried out during Ramadan, during which participants abstained from food and drink from pre-dawn (Imsak) until sunset (Maghrib).

The inclusion criteria were as follows:

- Male gender,
- Absence of known health conditions,
- Consistent adherence to fasting throughout Ramadan,
- No consumption of ergogenic aids or dietary supplements that could potentially influence performance,
- Full participation in all training sessions.

Participants were randomly assigned to either the Pre-Iftar or Post-Iftar training group using a simple randomization procedure. The High-Intensity Functional Training (HIFT) program was conducted three times per week for four weeks at XFIT Fitness Center in Karabük, with each training session standardized to a duration of 12 minutes. Participants' dietary intake was monitored daily, although their habitual dietary patterns were maintained throughout the study period.

The sample size (n = 32) limits the statistical power of the study, a limitation that is explicitly acknowledged. While no non-fasting control group was included, the study design enabled a comparative evaluation of the effects of training timing (Pre-Iftar vs. Post-Iftar) during Ramadan fasting.

Training Program

The high-intensity functional training (HİFT) program is presented in Table 1.

Table 1. High-intensity functional training program

Exercises	**Training Variables**
1. Squat / Lunge	Duration: 4 weeks Frequency (per week): 3 days Duration (min): HIFT: 8–18 min / Total: 35–50 min Sets/Reps: 8 exercises × 3 sets Work-to-Rest Ratio (sec): 30:15 / 20:10 Intensity (HRmax): 80% Pre-Iftar Group: Trained 2 hours before iftar Post-Iftar Group: Trained 2 hours after iftar
2. Lat Pull Down	
3. Sprinting in Place	
4. Push-up	
5. Box Step-ups	
6. Sidewalk Plank	
7. Deadlift	
8. Medicine Ball Toss	

Height Measurement

The height of the participants was measured using a stadiometer with a sensitivity level of 0.01 meters. Measurements were recorded in centimeters (cm) while participants stood barefoot, with heels together, knees fully extended, and in an upright position (10).

Body Composition Analysis

The participants' body weight (kg), body mass index (BMI, kg/m²), body fat percentage (%), muscle mass (kg), and fat-free mass index (FFMI) were measured using the InBody 270 professional bioelectrical impedance analysis (BIA) device (5,34). Pre-test measurements were conducted during the first week of Ramadan, in the morning between 09:00 and 10:00, immediately after the pre-dawn meal (sahur). Post-test measurements were obtained under the same conditions, during the last week of Ramadan, again in the morning between 09:00 and 10:00, immediately after sahur. This procedure ensured consistency in measurement conditions and enhanced the reliability of pre- and post-test comparisons. To further ensure the accuracy of the test results, participants were instructed to abstain from consuming any food or beverages for at least 4–5 hours prior to the assessment and to refrain from engaging in physical exercise within 12 hours before testing. Additionally, the device was disinfected after each participant's use.

Circumference Measurements

Circumference measurements were taken using a non-stretchable cloth tape with a width of 7 mm. During the measurement, one end of the tape was held in the left hand and set at the zero starting point, while the

other end was wrapped around the targeted reference area and held with the right hand to record the values. To minimize measurement errors and correctly identify reference points, participants wore shorts during both the pre- and post-tests (34).

Chest Circumference

The participant stands upright in a relaxed position. The measuring tape is placed horizontally around the chest at the level of the greatest circumference of the pectoral region. During the measurement, the tape is maintained parallel to the floor without compressing the soft tissues (4).

Shoulder Circumference

The participant stands upright with the arms relaxed at the sides. The measurement is taken by positioning the measuring tape around the shoulders, passing over the shoulder joints and encompassing the most lateral points of both shoulders. The tape is held level and parallel to the ground throughout the measurement (4).

Hip Circumference

Hip circumference is measured at the level of the greatest posterior and lateral extension of the buttocks. The measuring tape is positioned horizontally and kept parallel to the floor. Upper garments are lifted to ensure accurate placement of the tape (4).

Biceps Circumference

The participant allows the arm to hang freely in a relaxed position. The measuring tape is placed around the midpoint between the acromion process and the olecranon process. The measurement is taken without compressing the skin or underlying tissues (4).

Thigh Circumference

The participant stands in an upright position. The measuring tape is placed around the thigh at a level close to the midpoint between the hip and knee joints, corresponding to the area of maximum thigh girth. The tape is maintained parallel to the floor during the measurement (4).

Waist Circumference

Waist circumference is measured at the narrowest point of the torso or at the level of the natural waistline, corresponding to the region just above the iliac crest. The participant stands upright with the abdominal muscles relaxed. The measuring tape is placed in contact with the skin without exerting pressure (6).

Isometric Muscle Strength Test

A hand-held dynamometer was used for isometric muscle strength testing, fixed in place with the aid of an external belt. This setup minimized measurement errors that could arise from the tester, allowing for reliable assessment (27).

Static Strength Test

Muscle strength was measured using a Lafayette brand digital hand-held dynamometer. The Lafayette digital muscle testing device is a portable tool equipped with an LCD digital display and three interchangeable heads. The device is capable of providing data such as peak force, time to reach peak force, total test duration, and average force, in both kilogram-newtons and pounds. For quadriceps strength measurement, participants were seated on a flat surface with hips and knees in 90º flexion, feet unsupported, and in a position where they could not gain external support. Before beginning the test, participants were verbally instructed on the correct technique and testing procedure (11,23).

Hand Grip Strength

Hand grip strength was measured using a Takei TKK 5401 Grip-D digital hand dynamometer (Takei Scientific Instruments Co., Ltd., Japan). Participants were tested in a standing position with their arms alongside the body, elbows fully extended, and wrists in a neutral position. Measurements were obtained separately for the right and left hands (18).

Leg Strength

Leg strength was assessed using a Takei TKK 5002 leg dynamometer (Takei Scientific Instruments Co., Ltd., Japan). Participants performed the test with hips and knees flexed at approximately 120°, applying maximal pushing force against the chain connected to the dynamometer (26).

Back Strength

Back strength was measured with a Takei TKK 5002 back dynamometer (Takei Scientific Instruments Co., Ltd., Japan). During the test, participants stood with knees slightly flexed (~30°), maintained a straight back, and gripped the bar with a shoulder-width pronated grip. They were instructed to exert maximal pulling force upward (33).

RPE (Rate of Perceived Exertion)

The rate of perceived exertion (RPE) is a widely recognized metric that enables participants to subjectively evaluate exercise intensity (2). In the present study, RPE was assessed using the Borg 6–20 Scale, which provides values ranging from 6 (no exertion) to 20 (maximal exertion). Following each maximal strength assessment, participants' test-specific RPE scores were documented. This approach is extensively employed in scientific research to investigate the relationship between perceived exertion and objective physiological parameters.

Statistical Analysis

The data were analyzed using the SPSS 25 statistical software package. The Shapiro-Wilk test was employed to assess the normality of the data distribution. For parameters that did not follow a normal distribution, the Mann-Whitney U test was used to compare independent groups, and the Wilcoxon signed-rank test was applied for dependent group comparisons. The level of statistical significance was set at 0.05, and all analyses were conducted within a 95% confidence interval.

Ethical approval and institutional permission

This study was approved by the Ethics Committee of Bayburt University with the decision numbered E-15604681-100-194060 at the meeting dated 29.03.2024 and numbered 84. The research was conducted in accordance with the Declaration of Helsinki. All participants were included in the study after providing informed voluntary consent through a signed consent form.

FINDINGS

Table 2. Descriptive Statistics of Participants

Variable	Group	N	Minimum	Maximum	Mean	SD
Age (years)	**Pre-Iftar**	16	19,00	24,00	21,94	1,56
	Post-Iftar	16	19,00	28,00	23,50	2,70
Height (cm)	**Pre-Iftar**	16	167,00	188,00	176,06	7,78
	Post-Iftar	16	164,00	190,00	175,25	9,26
Body Weight (kg)	**Pre-Iftar**	16	69,46	102,00	81,92	10,69
	Post-Iftar	16	51,75	112,20	82,18	18,85
Body Fat (%)	**Pre-Iftar**	16	10,73	28,87	19,39	6,67
	Post-Iftar	16	4,20	35,12	19,10	9,61
Body Mass Index (kg/m²)	**Pre-Iftar**	16	21,90	31,30	26,19	3,00
	Post-Iftar	16	18,50	33,10	26,40	4,47
Muscle Mass (kg)	**Pre-Iftar**	16	52,20	69,55	59,42	5,78
	Post-Iftar	16	45,05	73,35	60,15	9,95

As presented in Table 2, the participants in the pre-iftar training group had a mean age of 21.94 ± 1.56 years, an average height of 176.06 ± 7.78 cm, a body weight of 81.92 ± 10.69 kg, a body fat percentage of 19.39 ± 6.67%, a body mass index (BMI) of 26.19 ± 3.00 kg/m², and a mean muscle mass of 59.42 ± 5.78 kg. Conversely, participants in the post-iftar training group exhibited a mean age of 23.50 ± 2.70 years, an average height of 175.25 ± 9.26 cm, a body weight of 82.18 ± 18.85 kg, a body fat percentage of 19.10 ± 9.61%, a BMI of

26.40 ± 4.47 kg/m², and a mean muscle mass of 60.15 ± 9.95 kg. These findings indicate that both groups demonstrated comparable anthropometric characteristics at baseline.

Table 3. Comparison of pre-test performance values between pre-ıftar and post-ıftar training groups

Variable	Pre-Iftar Mean±SD	Post-Iftar Mean±SD	U	p
Body Weight (kg)	81,92±10,69	82,18±18,85	121,000	0,792
Muscle Mass (kg)	59,42±5,78	60,15±9,95	123,000	0,850
Body Fat (%)	19,39±6,67	19,10±9,61	127,000	0,970
BMI (kg/m²)	26,19±3,00	26,40±4,47	120,000	0,762
Right Hand Grip (kg)	45,65±7,43	46,56±9,18	122,000	0,821
Left Hand Grip (kg)	45,43±4,15	47,78±12,77	128,000	1,000
Back Strength (kg)	143,43±29,53	143,75±25,39	111,500	0,529
Leg Strength (kg)	167,81±35,82	161,87±31,13	120,000	0,762
Shoulder Circumference (cm)	119,87±4,68	122,00±11,47	104,000	0,364
Chest Circumference (cm)	104,18±5,07	104,75±10,71	118,000	0,705
Right Biceps Circ. (cm)	36,75±1,52	35,25±4,78	108,000	0,442
Left Biceps Circ. (cm)	36,12±2,09	34,75±4,95	111,000	0,517
Waist Circumference (cm)	89,06±7,05	90,56±13,33	124,000	0,880
Right Thigh Circ. (cm)	58,06±6,00	58,56±5,26	118,000	0,704
Left Thigh Circ. (cm)	56,81±6,23	58,50±5,32	102,000	0,322
Right Hamstring (kg)	31,43±6,10	30,70±5,77	89,000	0,140
Left Hamstring (kg)	32,80±5,67	32,69±3,34	120,000	0,762
Right Quadriceps (kg)	36,25±8,92	33,28±5,20	107,000	0,427
Left Quadriceps (kg)	33,78±10,58	34,66±5,13	103,000	0,345
Right Gluteus Maximus (kg)	24,76±0,94	24,65±4,17	112,000	0,545
Left Gluteus Maximus (kg)	21,76±2,73	23,74±4,64	93,000	0,186
Right Gluteus Medius (kg)	21,70±5,90	21,31±3,99	121,000	0,791
Left Gluteus Medius (kg)	21,81±6,26	22,36±4,09	107,000	0,427
Right Latissimus Dorsi (kg)	14,06±4,68	13,17±2,51	118,000	0,706
Left Latissimus Dorsi (kg)	14,50±4,71	11,92±1,70	95,000	0,212
Right Triceps (kg)	20,95±4,21	19,18±2,83	104,000	0,363
Left Triceps (kg)	21,88±3,67	18,46±3,28	70,000	0,028*
Right Shoulder Int. Rot. (kg)	20,27±3,81	21,36±3,91	101,000	0,308
Left Shoulder Int. Rot. (kg)	20,66±3,36	20,68±4,02	128,000	1,000
Right Shoulder Ext. Rot. (kg)	18,71±4,29	17,45±4,62	99,000	0,272
Left Shoulder Ext. Rot. (kg)	19,82±3,83	16,33±4,02	65,000	0,017*
Right Lower Trapezius (kg)	11,18±3,82	11,38±5,31	116,000	0,650
Left Lower Trapezius (kg)	10,36±3,38	9,98±3,51	109,000	0,473
Isometric RPE (score)	10,81±2,56	13,00±2,42	68,500	0,022*
Back Strength RPE (score)	12,00±3,05	13,62±2,82	91,000	0,158
Leg Strength RPE (score)	11,06±4,15	13,87±2,80	95,000	0,209
Grip Strength RPE (score)	9,50±2,80	10,56±3,53	112,000	0,544

* $p<0,05$

Table 3 presents the comparison of pre-test performance values between the pre-iftar and post-iftar training groups. The analysis revealed statistically significant differences in the values of left triceps, left shoulder external rotation, and isometric RPE ($p < 0.05$). However, no significant differences were observed in the remaining parameters ($p > 0.05$).

Table 4. Comparison of post-test performance values between the pre-ıftar and post-ıftar training groups

Variable	Pre-Iftar Mean ± SD	Post-Iftar Mean ± SD	U	p
Body Weight (kg)	81,85 ± 10,51	81,58 ± 18,67	127,000	0,970
Muscle Mass (kg)	60,35 ± 6,05	60,84 ± 10,29	123,000	0,850
Body Fat (%)	18,37 ± 6,66	17,59 ± 9,10	124,000	0,880
BMI (kg/m²)	26,39 ± 2,93	26,15 ± 4,37	124,000	0,880
Right Hand Grip (kg)	48,08 ± 8,32	49,11 ± 8,82	120,000	0,763
Left Hand Grip (kg)	46,62 ± 5,55	49,69 ± 9,57	111,000	0,521
Back Strength (kg)	153,12 ± 32,13	149,37 ± 22,57	126,000	0,939
Leg Strength (kg)	178,75 ± 37,17	173,43 ± 29,19	123,000	0,850
Shoulder Circumference (cm)	124,62 ± 5,57	125,06 ± 10,98	110,000	0,495
Chest Circumference (cm)	106,31 ± 5,35	104,50 ± 11,12	128,000	1,000
Right Biceps Circ. (cm)	37,50 ± 1,26	35,81 ± 4,49	112,000	0,541
Left Biceps Circ. (cm)	37,43 ± 2,03	35,68 ± 4,78	105,000	0,382
Waist Circumference (cm)	88,00 ± 6,80	88,75 ± 12,27	115,000	0,623
Right Thigh Circ. (cm)	57,68 ± 4,39	58,31 ± 5,19	127,500	0,985
Left Thigh Circ. (cm)	55,87 ± 5,09	58,93 ± 5,33	94,500	0,199
Right Hamstring (kg)	34,26 ± 7,08	34,46 ± 9,92	126,000	0,940
Left Hamstring (kg)	36,95 ± 8,51	39,21 ± 9,54	103,000	0,345
Right Quadriceps (kg)	34,31 ± 8,06	29,07 ± 5,79	80,000	0,070
Left Quadriceps (kg)	29,88 ± 8,28	27,53 ± 6,48	112,000	0,546
Right Gluteus Maximus (kg)	30,65 ± 2,60	38,23 ± 7,03	42,000	0,001*
Left Gluteus Maximus (kg)	29,13 ± 5,40	40,17 ± 6,68	18,000	0,000*
Right Gluteus Medius (kg)	24,60 ± 4,12	26,55 ± 4,42	85,000	0,104
Left Gluteus Medius (kg)	24,33 ± 6,05	26,95 ± 6,19	90,000	0,151
Right Latissimus Dorsi (kg)	14,48 ± 4,12	13,10 ± 3,00	102,000	0,326
Left Latissimus Dorsi (kg)	14,60 ± 3,83	13,70 ± 3,96	104,500	0,375
Right Triceps (kg)	20,81 ± 4,48	21,18 ± 4,18	125,000	0,910
Left Triceps (kg)	21,73 ± 4,73	18,85 ± 4,23	85,000	0,104
Right Shoulder Int. Rot. (kg)	20,06 ± 2,83	21,95 ± 4,77	91,000	0,162
Left Shoulder Int. Rot. (kg)	18,16 ± 2,52	20,90 ± 5,25	80,000	0,070
Right Shoulder Ext. Rot. (kg)	17,72 ± 5,05	17,84 ± 4,97	124,000	0,880
Left Shoulder Ext. Rot. (kg)	18,30 ± 5,20	17,40 ± 3,41	112,000	0,546
Right Lower Trapezius (kg)	10,96 ± 3,97	9,38 ± 2,48	89,000	0,140
Left Lower Trapezius (kg)	9,65 ± 3,39	8,93 ± 2,67	97,000	0,241
Isometric RPE (score)	11,75 ± 2,54	13,31 ± 2,75	85,000	0,096
Back Strength RPE (score)	13,87 ± 3,22	13,68 ± 2,91	115,500	0,634
Leg Strength RPE (score)	11,56 ± 3,68	12,37 ± 2,77	111,000	0,517
Grip Strength RPE (score)	11,56 ± 3,16	10,37 ± 4,17	98,000	0,252

* $p<0,05$

Table 4 presents the comparison of post-test performance values between the pre-iftar and post-iftar training groups. The analysis revealed statistically significant differences in the right and left gluteus maximus values ($p < 0.05$). No statistically significant differences were found in the other parameters ($p > 0.05$).

Table 5. Comparison of pre-test and post-test values within the pre-ıftar training group

Variable	Pre-Test Mean ± SD	Post-Test Mean ± SD	Z	p
Body Weight (kg)	81,92 ± 10,69	81,85 ± 10,51	-1,140	0,254
Muscle Mass (kg)	59,42 ± 5,78	60,35 ± 6,05	-3,554	0,000*
Body Fat (%)	19,39 ± 6,67	18,37 ± 6,66	-2,695	0,007*
BMI (kg/m²)	26,19 ± 3,00	26,39 ± 2,93	-1,356	0,175
Right Hand Grip (kg)	45,65 ± 7,43	48,08 ± 8,32	-2,125	0,034*
Left Hand Grip (kg)	45,43 ± 4,15	46,62 ± 5,55	-2,130	0,033*
Back Strength (kg)	143,43 ± 29,53	153,12 ± 32,13	-3,337	0,001*
Leg Strength (kg)	167,81 ± 35,82	178,75 ± 37,17	-2,512	0,012*
Shoulder Circumference (cm)	119,87 ± 4,68	124,62 ± 5,57	-3,543	0,000*
Chest Circumference (cm)	104,18 ± 5,07	106,31 ± 5,35	-3,376	0,001*
Right Biceps Circ. (cm)	36,75 ± 1,52	37,50 ± 1,26	-3,464	0,001*
Left Biceps Circ. (cm)	36,12 ± 2,09	37,43 ± 2,03	-3,666	0,000*
Waist Circumference (cm)	89,06 ± 7,05	88,00 ± 6,80	-1,451	0,147
Right Thigh Circ. (cm)	58,06 ± 6,00	57,68 ± 4,39	-0,449	0,653
Left Thigh Circ. (cm)	56,81 ± 6,23	55,87 ± 5,09	-1,040	0,298
Right Hamstring (kg)	31,43 ± 6,10	34,26 ± 7,08	-2,073	0,038*
Left Hamstring (kg)	32,80 ± 5,67	36,95 ± 8,51	-1,972	0,049*
Right Quadriceps (kg)	36,25 ± 8,92	34,31 ± 8,06	-0,104	0,917
Left Quadriceps (kg)	33,78 ± 10,58	29,88 ± 8,28	-3,368	0,001*
Right Gluteus Maximus (kg)	24,76 ± 0,94	30,65 ± 2,60	-3,524	0,000*
Left Gluteus Maximus (kg)	21,76 ± 2,73	29,13 ± 5,40	-3,524	0,000*
Right Gluteus Medius (kg)	21,70 ± 5,90	24,60 ± 4,12	-2,125	0,034*
Left Gluteus Medius (kg)	21,81 ± 6,26	24,33 ± 6,05	-1,762	0,078
Right Latissimus Dorsi (kg)	14,06 ± 4,68	14,48 ± 4,12	-0,728	0,466
Left Latissimus Dorsi (kg)	14,50 ± 4,71	14,60 ± 3,83	-1,380	0,168
Right Triceps (kg)	20,95 ± 4,21	20,81 ± 4,48	0,000	1,000
Left Triceps (kg)	21,88 ± 3,67	21,73 ± 4,73	-0,623	0,533
Right Shoulder Int. Rot. (kg)	20,27 ± 3,81	20,06 ± 2,83	-0,570	0,569
Left Shoulder Int. Rot. (kg)	20,66 ± 3,36	18,16 ± 2,52	-2,130	0,033*
Right Shoulder Ext. Rot. (kg)	18,71 ± 4,29	17,72 ± 5,05	-1,036	0,300
Left Shoulder Ext. Rot. (kg)	19,82 ± 3,83	18,30 ± 5,20	-2,228	0,026*
Right Lower Trapezius (kg)	11,18 ± 3,82	10,96 ± 3,97	-1,609	0,108
Left Lower Trapezius (kg)	10,36 ± 3,38	9,65 ± 3,39	-0,208	0,835
Isometric RPE (score)	10,81 ± 2,56	11,75 ± 2,54	-3,419	0,001*
Back Strength RPE (score)	12,00 ± 3,05	13,87 ± 3,22	-2,250	0,024*
Leg Strength RPE (score)	11,06 ± 4,15	11,56 ± 3,68	-0,860	0,390
Grip Strength RPE (score)	9,50 ± 2,80	11,56 ± 3,16	-3,568	0,000*

* **p<0,05**

As shown in Table 5, a statistically significant difference was observed between the pre-test and post-test values of the pre-iftar training group in the following parameters: body weight, muscle mass, right hand grip strength, left hand grip strength, back strength, leg strength, shoulder circumference, chest circumference, right biceps circumference, left biceps circumference, right hamstring, left hamstring, left quadriceps, right gluteus maximus, left gluteus maximus, right gluteus medius, left shoulder internal rotation, left shoulder external rotation, isometric RPE, back strength RPE, and grip strength RPE ($p < 0.05$). For the remaining variables, no statistically significant differences were found between pre- and post-test measurements ($p > 0.05$).

Table 6. Comparison of pre-test and post-test values within the post-ıftar training group

Variable	Pre-Test Mean ± SD	Post-Test Mean ± SD	Z	p
Body Weight (kg)	82,18 ± 18,85	81,58 ± 18,67	-1,452	0,146
Muscle Mass (kg)	60,15 ± 9,95	60,84 ± 10,29	-3,158	0,002*
Body Fat (%)	19,10 ± 9,61	17,59 ± 9,10	-3,520	0,000*
BMI (kg/m²)	26,40 ± 4,47	26,15 ± 4,37	-2,236	0,025*
Right Hand Grip (kg)	46,56 ± 9,18	49,11 ± 8,82	-2,333	0,020*
Left Hand Grip (kg)	47,78 ± 12,77	49,69 ± 9,57	-1,521	0,128
Back Strength (kg)	143,75 ± 25,39	149,37 ± 22,57	-1,294	0,196
Leg Strength (kg)	161,87 ± 31,13	173,43 ± 29,19	-3,477	0,001*
Shoulder Circumference (cm)	122,00 ± 11,47	125,06 ± 10,98	-3,181	0,001*
Chest Circumference (cm)	104,75 ± 10,71	104,50 ± 11,12	-0,539	0,590
Right Biceps Circ. (cm)	35,25 ± 4,78	35,81 ± 4,49	-2,496	0,013*
Left Biceps Circ. (cm)	34,75 ± 4,95	35,68 ± 4,78	-3,638	0,000*
Waist Circumference (cm)	90,56 ± 13,33	88,75 ± 12,27	-2,345	0,019*
Right Thigh Circ. (cm)	58,56 ± 5,26	58,31 ± 5,19	-0,457	0,648
Left Thigh Circ. (cm)	58,50 ± 5,32	58,93 ± 5,33	-0,159	0,873
Right Hamstring (kg)	30,70 ± 5,77	34,46 ± 9,92	-1,605	0,109
Left Hamstring (kg)	32,69 ± 3,34	39,21 ± 9,54	-2,796	0,005*
Right Quadriceps (kg)	33,28 ± 5,20	29,07 ± 5,79	-2,744	0,006*
Left Quadriceps (kg)	34,66 ± 5,13	27,53 ± 6,48	-3,520	0,000*
Right Gluteus Maximus (kg)	24,65 ± 4,17	38,23 ± 7,03	-3,520	0,000*
Left Gluteus Maximus (kg)	23,74 ± 4,64	40,17 ± 6,68	-3,520	0,000*
Right Gluteus Medius (kg)	21,31 ± 3,99	26,55 ± 4,42	-3,365	0,001*
Left Gluteus Medius (kg)	22,36 ± 4,09	26,95 ± 6,19	-2,692	0,007*
Right Latissimus Dorsi (kg)	13,17 ± 2,51	13,10 ± 3,00	-0,311	0,756
Left Latissimus Dorsi (kg)	11,92 ± 1,70	13,70 ± 3,96	-1,915	0,055
Right Triceps (kg)	19,18 ± 2,83	21,18 ± 4,18	-2,958	0,003*
Left Triceps (kg)	18,46 ± 3,28	18,85 ± 4,23	-0,052	0,959
Right Shoulder Int. Rot. (kg)	21,36 ± 3,91	21,95 ± 4,77	-0,569	0,569
Left Shoulder Int. Rot. (kg)	20,68 ± 4,02	20,90 ± 5,25	-0,855	0,393
Right Shoulder Ext. Rot. (kg)	17,45 ± 4,62	17,84 ± 4,97	-0,830	0,407
Left Shoulder Ext. Rot. (kg)	16,33 ± 4,02	17,40 ± 3,41	-1,398	0,162
Right Lower Trapezius (kg)	11,38 ± 5,31	9,38 ± 2,48	-1,709	0,087
Left Lower Trapezius (kg)	9,98 ± 3,51	8,93 ± 2,67	-1,139	0,255
Isometric RPE (score)	13,00 ± 2,42	13,31 ± 2,75	-0,904	0,366
Back Strength RPE (score)	13,62 ± 2,82	13,68 ± 2,91	-0,478	0,633
Leg Strength RPE (score)	13,87 ± 2,80	12,37 ± 2,77	-2,690	0,007*
Grip Strength RPE (score)	10,56 ± 3,53	10,37 ± 4,17	-0,553	0,581

* $p<0,05$

As shown in Table 6, statistically significant differences were observed between the pre-test and post-test values within the post-iftar training group in the following parameters: muscle mass, body fat percentage, BMI, right hand grip strength, leg strength, shoulder circumference, right biceps circumference, left biceps circumference, waist circumference, left hamstring, right quadriceps, left quadriceps, right gluteus maximus, left gluteus maximus, right gluteus medius, left gluteus medius, right triceps, and leg strength RPE ($p < 0.05$). No statistically significant differences were found in the remaining variables ($p> 0.05$).

DISCUSSION AND CONCLUSION

The combined effects of fasting and exercise on body composition, metabolic health, and muscle performance have been widely discussed in recent years. Particularly, significant differences in muscle strength, body composition, and aerobic capacity have been observed between individuals who perform exercise before and after iftar, highlighting the diverse physiological impacts of fasting-exercise combinations.

In our study, the effects of resistance training timing during Ramadan on muscle strength were investigated. Our findings indicate that training conducted in the post-iftar period resulted in greater improvements in both isometric and dynamic muscle strength compared to training performed in the pre-iftar (fasted) state. These results are consistent with the findings of Triki et al. (31), who reported that performing resistance training after iftar during Ramadan optimizes gains in muscle strength. The comparatively limited strength development observed with pre-iftar training may be attributed to metabolic constraints associated with reduced glycogen stores and dehydration. These findings suggest that, during Ramadan, scheduling resistance training in alignment with nutritional intake and hydration status is an important strategy for maximizing muscle strength adaptations.

In Table 3, a comparison of the pre-test performance values between the pre-iftar and post-iftar training groups revealed statistically significant differences in left triceps strength, left shoulder external rotation, and isometric RPE ($p < 0.05$), while other parameters showed no significant differences ($p > 0.05$). These findings are consistent with previous research indicating that exercise performance and recovery may be influenced by fasting state and nutrient timing. For instance, Dannecker et al. (8) noted that fasting does not directly prevent muscle damage but may alter inflammatory markers like nitric oxide and TNF-alpha. Similarly, Rashedi and Nussbaum (17) emphasized that muscle recovery is influenced by prior fatigue history, potentially explaining the observed differences in isometric RPE.

Table 4 illustrates the comparison of post-test performance values between both groups. A statistically significant difference was found in both right and left gluteus maximus strength values in favor of the post-iftar training group ($p < 0.05$). As large muscle groups, the gluteus maximus muscles are critical for lower limb strength and hip stability. The improvement in these muscles supports the hypothesis that postprandial exercise enhances hypertrophic adaptations. Studies such as that by Nunes et al. (15) have shown that high-intensity exercise combined with nutrient intake can significantly enhance muscle strength and hypertrophy, particularly in postmenopausal women. These results affirm the potential benefits of training after iftar, especially in promoting gains in larger muscle groups.

The absence of significant differences in other muscle groups may suggest that these muscles are less sensitive to energy availability or were not as extensively engaged during training. Correia et al. (7), in a systematic review, found that Ramadan fasting might negatively affect aerobic capacity and muscular endurance, which may account for the inconsistent responses among different muscle groups.

Table 5 presents a within-group analysis for the pre-iftar training group. Statistically significant improvements were observed in variables such as body weight, muscle mass, grip strength, back and leg strength, upper body circumferences, and RPE values ($p < 0.05$). These findings align with the work of Martínez-Rodríguez et al. (13), who reported that pre-iftar exercise may increase growth hormone levels, supporting muscle development even in the fasted state. Improvements in perceived exertion and endurance further suggest positive neuromuscular adaptations from fasted training.

Table 6 provides a within-group comparison for the post-iftar group, where significant increases were observed in muscle mass, reductions in fat percentage and BMI, as well as improvements in strength, hypertrophy-related circumferences, and RPE values ($p < 0.05$). These findings are consistent with the notion that high-intensity exercise performed after feeding may have enhanced muscle protein synthesis and fat metabolism, thereby reinforcing the existing literature. (13,15). The notable improvements in gluteus maximus and gluteus medius highlight the responsiveness of large muscle groups to nutrient-supported resistance training.

The lack of significance in certain parameters may be attributed to insufficient stimulus or reduced responsiveness of some muscle groups to fasting or feeding states. Correia et al. (7) further emphasize that the effects of Ramadan fasting on performance are variable, possibly depending on training type and muscle group involvement.

This study demonstrated that high-intensity functional training during Ramadan yields significant improvements in muscle strength, hypertrophy, and body composition. Post-iftar exercise, in particular, showed enhanced effects on large muscle groups, likely due to optimized nutrient availability and recovery

conditions. The findings support existing literature indicating that nutrient timing plays a key role in maximizing exercise benefits under intermittent fasting conditions.

Nonetheless, several limitations should be considered. The sample was relatively small and homogeneous in terms of age and sex, which may limit the generalizability of the findings. Nutrition, hydration, and sleep patterns were self-reported and may have introduced potential variability. The 4-week training program may not fully reflect long-term adaptations, and some muscle groups may not have received sufficient activation to elicit significant changes. Moreover, hormonal and biochemical responses were not assessed, which limits mechanistic explanations. Future studies involving larger and more diverse populations, longer-term training interventions, and physiological measurements are warranted to better elucidate the interactions between fasting, nutrition, and exercise timing.

Overall, the findings indicate that high-intensity functional training during Ramadan is effective in improving muscle strength, hypertrophy, and body composition, with post-iftar training particularly promoting development in larger muscle groups. This study provides a foundation for future research on individualized training strategies and optimizing exercise timing under intermittent fasting conditions.

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